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Description

Optical Component for Terahertz Wave Transmission, Terahertz Wave Optical System, Terahertz Band Wave Processing Apparatus and Method

Technical Field

The present invention relates to an optical component for terahertz wave, a terahertz wave optical system, a terahertz band wave processing apparatus and method and, for example, relates to an optical component for terahertz wave, a terahertz band wave processing apparatus and method capable of making easier use of terahertz light more effectively.

Background Art

(Patent Reference 1)

JP-A-2002-303574

(Patent Reference 2)

JP-A-2002-246664

(Patent Reference 3)

JP-A-2002-223017

Conventionally, terahertz band electromagnetic waves are invisible light in a normal state. Such terahertz band light is electromagnetic waves present in a zone of wavelengths of 3 mm to 30 μm and frequencies of 100 GHz to 10 THz, and is used in inspection, measurement, imaging of

a substance and various other fields.

As described above, the terahertz light cannot be seen directly by human eyes. Fig. 5 shows a frequency distribution of wavelengths ranging from a very low frequency wave (VLF) to a gamma ray. In this frequency band, it is apparent that visible light (visible ray) is wavelength light of a very narrow frequency band in the range of an infrared ray to an ultraviolet ray.

It is apparent from Fig. 5 that terahertz electromagnetic waves are invisible rays, and are present in a wavelength region in the range of an extremely-high frequency wave (EHF) to a far-infrared ray. In the terahertz electromagnetic waves, commercialization has proceeded particularly in recent years and the emergence of a simple observation tool capable of observing and adjusting the optical axis of terahertz light has been desired. The following arts have been proposed as the observation tool based on these desires.

In Patent Reference 1, alignment of a terahertz optical system is adjusted while a terahertz light source of a dipole antenna etc. is replaced with a pinhole etc. and visible light or near-infrared light (in many cases, pump light itself) is passed through the pinhole and a situation of its transmitted light is observed. That is, the adjustment is made by considering that an optical path of the transmitted light of the pinhole is the same as an optical path of the terahertz light.

Incidentally, in the case of visible light, its radiation position etc. can be observed directly with the naked eye. In the case of near-infrared light etc., observation can be made easily by using a simple and easy observation tool such as a card type infrared sensor (for example, "SIRC-(1)" (trade name) commercially available from Sigma Koki Co., Ltd.) in which material for emitting visible light in response to the near-infrared light is applied to a sheet member.

The art of Patent Reference 2 is a single-crystal inherent Josephson junction terahertz detector capable of surely joining a terahertz signal system to an inherent Josephson junction position. In the single-crystal inherent Josephson junction terahertz detector, its configuration comprises a substrate, a Josephson junction device inherent in a perfect superconducting single crystal ($Bi_2Sr_2Cu_2O_8$) manufactured in a two-sided processing process mounted on this substrate, and an antenna integrated into this Josephson junction device.

A terahertz photodetector comprising a terahertz optical element, a radiation part for radiating a predetermined place of said terahertz optical element with femtosecond pulsed light from the side opposite to a substrate, and a current detection part for detecting a current passing between two conductive films is disclosed in Patent Reference 3.

The terahertz optical element comprises a substrate,

a photoconductive film formed on a plane of this substrate, and two conductive films mutually separated and formed on the photoconductive film. Portions of the conductive films are mutually arranged at a predetermined spacing d in a direction along the plane of the substrate. The substrate is formed so as to perform lens action on terahertz light which is emitted from the substrate to the side opposite to the photoconductive film or enters the substrate from the side opposite to the photoconductive film.

However, electromagnetic waves of a terahertz band have a high attenuation rate as compared with rays of a visible light region. The present characteristics are also apparent from Fig. 4. In Fig. 4, a graph (b) shows characteristics of attenuation rates to wavelengths (THz) in the case of transmitting electromagnetic waves of the terahertz band to conventional polyethylene with a plate thickness of 2 mm. It is apparent from the present graph (b) that transmission characteristics decrease suddenly as a frequency becomes high. Also, the terahertz band is invisible light and has a problem that handling of the invisible light is difficult as compared with visible light.

Also, in the conventional arts disclosed, it is very difficult to accurately replace the terahertz light source in the same position as that of the pinhole in Patent Reference 1. As a result of this, by only replacing the pinhole with the terahertz light source after alignment of the terahertz optical system is adjusted with reference to

the transmitted light of the pinhole, its alignment cannot be adjusted accurately.

As a result of that, in the conventional adjustment method for adjusting alignment of the present terahertz optical system, the alignment of the terahertz optical system is actually readjusted and optimized so that intensity increases while measuring the intensity of a detection signal of terahertz light after being replaced with a light source of the pinhole.

In work of this optimization, repeats of trial and error in which the alignment of the terahertz optical system is gradually changed with the help of the intensity of the detection signal of the terahertz light are indispensable. Therefore, in the present conventional adjustment method, the repeats of trial and error described above are required in order to accurately perform the alignment of the terahertz optical system. As a result of this, a problem of taking vast amounts of time and effort is involved.

In the art of Patent Reference 2, it is necessary to use superconducting material and the art has problems that cost is high and also production is difficult.

The art of Patent Reference 3 has a problem that its production is complicated.

Also, generally in recognition of terahertz waves, a bolometer using liquid helium is known. However, this art has a problem of requiring a large-scale measurement system.

An object of the present invention is to provide a low-cost and easy-to-produce optical component for terahertz wave, a terahertz band wave processing apparatus and method.

Disclosure of the Invention

An optical component for terahertz wave transmission of the present invention is characterized by comprising cycloolefin.

It is characterized in that the optical component is any of a lens, a prism, a beam supplier, a beam splitter, a fiber, a waveguide, a mirror, a polarizer and a window.

A terahertz optical system of the present invention is characterized by having a terahertz wave generation source, and an optical component comprising cycloolefin arranged on the optical axis of terahertz waves generated from said terahertz generation source.

A terahertz band wave processing apparatus of the present invention is configured to have a terahertz wave generator for generating predetermined terahertz waves, a terahertz wave detector for detecting the terahertz waves, a first light transmission regulator for defining a light transmission path between the terahertz wave generator and the terahertz wave detector and regulating the optical axis, a light semi-transmissive plate for transmitting terahertz waves on the optical axis between the first light transmission regulator and the terahertz wave detector and

reflecting light incident at a predetermined incident angle, and a second light transmission regulator set on the optical axis between the light semi-transmissive plate and the terahertz wave detector, and is characterized in that predetermined visible light enters the light semi-transmissive plate as pilot light and is reflected by said light semi-transmissive plate and the optical axis of said reflected visible light is superimposed on the optical axis of the terahertz waves and the optical axis of said terahertz waves can be visually recognized in a simulated manner by the visible light.

Also, preferably, the above terahertz wave detector is an Si bolometer, and the apparatus further has at least one pilot light guide mirror for use as optical axis adjustment of the pilot light entering the light semi-transmissive plate, and a visible light laser is used as the pilot light, and an aperture is applied to the light transmission regulator and a cycloolefin plate is applied to the light semi-transmissive plate, respectively.

A terahertz band wave processing method of the present invention is configured to have a detector position adjustment step of adjusting a direction and a position of a detector for detecting predetermined terahertz waves to a traveling direction of said terahertz waves, an aperture setting step of setting at least one aperture in a position in which a measured value of the detector does not decrease, and a pilot optical axis adjustment step of passing

predetermined pilot light through the aperture using a pilot light guide mirror and coaxially superimposing the optical axis of said pilot light on the optical axis of the terahertz waves, and is characterized in that predetermined visible light is used as pilot light and the optical axis of said visible light is superimposed on the optical axis of the terahertz waves and the optical axis of said terahertz waves can be visually recognized in a simulated manner by the visible light.

Action of the present invention will be described below along with knowledge obtained in the case of implementing the present invention.

Whereas cycloolefin was conventionally used as material of an optical system component, the present inventors found that said component had good transmission characteristics with respect to terahertz waves as a result of more specifically examining characteristics of the optical component made of cycloolefin.

In addition, they found that said component also had good transmission characteristics with respect to visible light. Further, they found that a difference between visible light and terahertz light in a refractive index was 0.01 or less. As a result of that, since the difference in the refractive index is very small though wavelengths of both the visible light and terahertz light are very separate, the lights are collected in the same place even in the case of passing through an optical component such as

a lens, so that the visible light can be used as pilot light. After all, for example, when the optical axis of terahertz waves is always matched with the optical axis of the visible light, the optical axis of the terahertz waves can be known by seeing the visible light.

The present invention is means for increasing the uses by finding new characteristics of the optical component made of cycloolefin as described above.

Here, high polymeric substances are preferably used as cycloolefin. A polymer (cycloolefin polymer) or a copolymer (cycloolefin copolymer) is preferably used. The cycloolefin polymer is available as a trade name of ZEONEX (registered trademark), and the cycloolefin copolymer is available as a trade name of APEL (manufactured by Mitsui Chemicals, Inc.).

Brief Description of the Drawings

Fig. 1 shows a first processing procedure example to which an embodiment of an optical component for terahertz wave, a terahertz band wave processing apparatus and method of the present invention is applied.

Fig. 2 is a system diagram showing a configuration example of a terahertz band wave processing apparatus to which a step 2 is applied.

Fig. 3 is a system diagram showing a configuration example of a terahertz band wave processing apparatus to which a step 3 is applied.

Fig. 4 is a graph showing a characteristic example of light transmittance in comparison between a cycloolefin polymer and polyethylene.

Fig. 5 shows a frequency distribution of wavelengths ranging from a very low frequency wave (VLF) to a gamma ray.

Fig. 6 is a graph showing light transmittance in the case of a cycloolefin copolymer.

(Description of Reference Numerals and Signs)

1,2,3 Aperture

4 Cycloolefin Plate

5 Si Bolometer (Detector)

10 Terahertz Wave Generator

11 Terahertz Wave

12 Pilot Light

21,22 Pilot Light Guide Mirror

Best Mode for Carrying Out the Invention

Next, an embodiment of an optical component for terahertz wave, a terahertz band wave processing apparatus and method according to the present invention will be described in detail with reference to the accompanying drawings. Referring to Figs. 1 to 4, one embodiment of an optical component for terahertz wave, a terahertz band wave processing apparatus and method of the present invention is shown.

Figs. 1 to 3 show a processing procedure example of coaxially superimposing a pilot beam (visible light) on

terahertz waves. A processing procedure of the embodiment is constructed based on the corresponding processing of a step 1 to a step 3 shown in Fig. 1 to Fig. 3. The present alignment procedure example is shown below.

(Step 1)

Fig. 1 is a system diagram showing a configuration example of an optical component for terahertz wave, a terahertz band wave processing apparatus and method to which a step 1 is applied. In the present Fig. 1, the optical component for terahertz wave, the terahertz band wave processing apparatus and method to which the step 1 is applied are configured to have a terahertz wave generator 10 of a parametric oscillator type, an aperture 3, a cycloolefin plate 4, and an Si bolometer (detector) 5. Terahertz waves 11 are outputted from the terahertz wave generator 10. The transmission optical axis of the aperture 1 is set at the optical axis of the terahertz waves 11 outputted. The cycloolefin plate 4 is set in the front and back of the plate in a state of transmitting the terahertz waves 11. Further, a direction and a position of the Si bolometer 5 are adjusted to a direction perpendicular to the optical axis of the terahertz waves.

(Step 2)

Fig. 2 is a diagram showing a second processing procedure example of coaxially superimposing a pilot beam (visible light) 12 on terahertz waves, and is a system diagram showing a configuration example of an optical

component for terahertz wave, a terahertz band wave processing apparatus and method to which a step 2 is applied. In the present Fig. 2, an aperture 2 and an aperture 3 are further added in addition to the optical component for terahertz wave, the terahertz band wave processing apparatus and method to which the step 1 shown in Fig. 1 is applied. In the present step 2, the aperture 2 and the aperture 3 are newly added and set between a cycloolefin plate 4 and an Si bolometer 5. In this addition and setting, the aperture 2 and the aperture 3 are set in a position in which a detection measured value of a terahertz wave signal of the Si bolometer 5 does not decrease. The present setting requires that the optical axes of transmission holes of the aperture 2 and the aperture 3 added should be matched with the optical axis of terahertz waves 11.

(Step 3)

Fig. 3 shows a third processing procedure example, and is a system diagram showing a configuration example of an optical component for terahertz wave, a terahertz band wave processing apparatus and method to which a step 3 is applied. In the present Fig. 3, a pilot light guide mirror 21 and a pilot light guide mirror 22 are further added and set in addition to the optical component for terahertz wave, the terahertz band wave processing apparatus and method to which the step 2 shown in Fig. 2 is applied. In the present step 3, after the addition processing of these

pilot light guide mirror 21 and pilot light guide mirror 22, for example, pilot light 12 of a visible light laser is superimposed on terahertz waves 11.

The pilot light guide mirror 21 and the pilot light guide mirror 22 are added, and the pilot light 12 of the visible light laser is coaxially superimposed on the terahertz waves 11 by setting angle adjustment of the pilot light guide mirror 21 and the pilot light guide mirror 22. In the present processing, a setting position, a setting angle, etc. of the pilot light guide mirror 21 and the pilot light guide mirror 22 are adjusted so that the optical axis of the pilot light 12 is superimposed on the axis of the terahertz waves 11 to a cycloolefin plate 4. By this position setting and angle adjustment, the optical axis of the pilot light 12 is superimposed on the optical axis of the terahertz waves 11.

The optical axis of the pilot light 12 can also be adjusted while making a check by a look because of visible light besides while checking an output signal of an Si bolometer 5. By the present adjustment, the optical axis of the pilot light 12 and the optical axis of the terahertz light 11 can be set at the same axis. The optical axis of the terahertz light after coaxially superimposing the pilot light 12 on the terahertz light 11 becomes a visible state in a simulated and artificial manner.

In the embodiment of the optical component for terahertz wave, the terahertz band wave processing

apparatus and method of the above configuration, it is necessary to further increase reflection characteristics with respect to the pilot light 12 and further decrease attenuation characteristics with respect to the terahertz light 11 as the cycloolefin plate 4. A concrete example of this cycloolefin plate 4 includes high-function resin (trade name; ZEONEX, Nippon Zeon Co., Ltd.). Fig. 4 shows a characteristic example of light transmittance in comparison between polyethylene and this trade name; ZEONEX (ZEONEX).

In Fig. 4, the axis of abscissa is a frequency [THz/terahertz] and the axis of ordinate is transmittance [Transmittance]. In two graphs in Fig. 4, the upper (a) is a characteristic graph of ZEONEX and the lower (b) is a characteristic graph of polyethylene, respectively. It is apparent from the present Fig. 4 that ZEONEX has better transmission characteristics. Incidentally, test specimens of the same thickness are used in both the measurement.

In application as the cycloolefin plate 4 of high-function resin, it is determined that use can be made in AR coat (anti-reflection coat) material for terahertz wave. Reflection can be reduced by forming thicknesses according to wavelengths on various optics optical planes for terahertz. Various application examples of the high-function resin are listed below.

(Various lens materials for terahertz wave)

Lenses with the same forms as those of various lenses

used in optics, for example, plano-convex, double-convex, concave, rod or cylindrical can be produced. And, the function as the cycloolefin plate 4 can be performed simultaneously with respect to visible light and terahertz waves.

(Materials for various prisms for terahertz)

Lenses with the same forms as those of various lenses used in optics, for example, 45° , right angle, roof or dove can be produced. And, the function as the cycloolefin plate 4 can be performed simultaneously with respect to visible light and terahertz waves.

(Application to beam splitter, beam supplier for terahertz wave)

A beam supplier or a beam splitter for splitting one terahertz wave into a surface reflected wave and a transmitted wave can be produced by being processed into plate shape. And, the function as the cycloolefin plate 4 can be performed simultaneously with respect to visible light and terahertz waves.

(Fiber material for terahertz wave)

Terahertz waves having a disadvantage in propagating through the air can be handled easily by being formed into fiber. And, the function as the cycloolefin plate 4 can be performed simultaneously with respect to visible light and terahertz waves.

(Waveguide material for terahertz wave)

Terahertz waves having a disadvantage in propagating

through the air can be propagated with high efficiency by being formed into waveguide shape. And, the function as the cycloolefin plate 4 can be performed simultaneously with respect to visible light and terahertz waves.

(Use in experiment for terahertz wave)

By using high transmission characteristics of terahertz waves, use in experiment in spectroscopy etc. can be made by being processed into a prepared slide (plate shape) or a sample (column shape) case, etc. and putting or inserting a specimen. And, the function as the cycloolefin plate 4 can be performed simultaneously with respect to visible light and terahertz waves.

(First mirror material for terahertz wave)

Substrate material of a dichroic mirror is formed by utilizing characteristics of transmitting terahertz waves.

(Second mirror material for terahertz wave)

A high-accurate and high-efficient half mirror for terahertz wave can be produced by utilizing characteristics of transmitting terahertz waves and including linear metal in the surface or the inside.

(Polarizer for terahertz wave)

A high-accurate and high-efficient polarizer for terahertz wave can be produced by utilizing characteristics of transmitting terahertz waves and including linear metal in the surface or the inside.

(Window material for terahertz wave)

Window material of a terahertz wave device is formed

by utilizing characteristics of transmitting terahertz waves. And, the present function can be performed simultaneously with respect to visible light and terahertz waves. Also, by arranging a window at a Brewster angle with respect to the terahertz waves, the terahertz waves can be transmitted at the value infinitely close to transmittance which the present material has.

(Material alternative to low refractive index dispersion semiconductor material such as silicon)

When a semiconductor such as silicon, germanium or gallium arsenide generally used as low refractive dispersion material is used together with visible light in a terahertz band, the semiconductor absorbs the visible light and reduces transmittance of terahertz waves. For example, high efficiency can be achieved by being replaced with the above semiconductor part of a terahertz wave generator or an experiment system simultaneously radiated with terahertz waves and visible light.

Incidentally, the embodiment described above is one example of preferred embodiments of the present invention. However, the present invention is not limited to this embodiment and various modifications can be made without departing from the gist of the present invention.

Configuration examples of diversification and effect examples associated with the diversification are listed below.

Fig. 6 shows a result of carrying out a transmission

test on terahertz waves using a trade name of APEL manufactured by Mitsui Chemicals, Inc. as cycloolefin. Incidentally, said test was carried out at an incident angle of 0° using a lens with a thickness of 3.5 mm. Also in the present example, good transmittance was obtained.

Incidentally, a thickness of an optical component in the present invention is not particularly limited. Also, an incident angle of terahertz waves is not particularly limited and is useful in the wide range.

Industrial Applicability

As is evident from the above description, a terahertz band wave processing apparatus of the present invention is configured to generate predetermined terahertz waves and dispose an optics optical plane constructed of high-function resin in the front of a traveling direction of this generated terahertz waves. By the present configuration, the apparatus with excellent transmission characteristics of terahertz band waves can be configured.